RADAR Titan Flyby during S78/T91

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March 13, 2014

- Sequence: s78
- Rev: 190
- Observation Id: t91
- Target Body: Titan
- Data Take Number: 248
- PDT Config File: S78_sip_port3_130124_pdt.cfg
- SMT File: s78_port3_130116.smt
- PEF File: z0780b.pef

1 Introduction

This memo describes the Cassini RADAR activities for the T91 Titan flyby. This SAR data collection occurs during the S78 sequence of the Saturn Tour. This is a full radar pass with SAR imaging in the north polar area crossing T16, T18 and T19. A sequence design memo provides the science context of the scheduled observations, an overview of the pointing design, and guidlines for preparing the RADAR IEB.

2 CIMS and Division Summary

CIMS ID	Start	End	Duration	Comments
190TI_T91WARMUP001_RIDER	2013-143T08:17:55	2013-143T11:32:55	03:15:0.0	
190TI_T91INRAD001_PRIME	2013-143T11:32:55	2013-143T15:17:55	03:45:0.0	
190TI_T91INSCAT001_PRIME	2013-143T15:17:55	2013-143T16:20:55	01:03:0.0	
190TI_T91IHISAR001_PRIME	2013-143T16:20:55	2013-143T17:01:55	00:41:0.0	
190TI_T91INALT001_PRIME	2013-143T17:02:55	2013-143T17:14:55	00:12:0.0	
190TI_T91INOSAR001_PRIME	2013-143T17:14:55	2013-143T17:50:55	00:36:0.0	
190TI_T91OUTALT001_PRIME	2013-143T17:50:55	2013-143T18:02:55	00:12:0.0	
190TI_T91OHISAR001_PRIME	2013-143T18:02:55	2013-143T18:22:55	00:20:0.0	
190TI_T91OUTSCT001_PRIME	2013-143T18:44:55	2013-143T19:47:55	01:03:0.0	
190TI_T91OUTRAD001_PRIME	2013-143T19:47:55	2013-143T23:32:55	03:45:0.0	

Table 1: t91 CIMS Request Sequence

Division	Name	Start	Duration	Data Vol	Comments
a	Warmup	-9:20:0.0	03:35:0.0	12.8	Warmup
b	standard_radiometer_inbound	-5:45:0.0	00:05:0.0	0.3	radiometer quick-steps
c	standard_radiometer_inbound	-5:40:0.0	03:20:0.0	11.9	radiometer raster
d	standard_scatterometer_inbound	-2:20:0.0	01:03:0.0	113.4	Inbound scatterometry raster
e	scatterometer_imaging	-1:17:0.0	00:14:0.0	67.2	Inbound scatterometer imaging
f	scatterometer_imaging	-1:03:0.0	00:01:6.0	5.3	Inbound scatterometer imaging
g	scatterometer_imaging	-1:01:54.0	00:32:24.0	155.5	Inbound scatterometer imaging
h	scatterometer_imaging	-0:29:30.0	00:01:18.0	6.2	Inbound scatterometer imaging
i	standard_altimeter_inbound	-0:28:12.0	00:08:12.0	15.7	Inbound altimetry
j	standard_scatterometer_inbound	-0:20:0.0	00:00:4.0	0.6	Atmospheric Probe with Chirp
k	standard_scatterometer_inbound	-0:19:56.0	00:00:2.0	0.3	Atmospheric Probe with Tone
l	standard_sar_hi	-0:19:54.0	00:01:24.0	4.2	SAR Turn transition, beam 3 only
m	standard_sar_hi	-0:18:30.0	00:02:30.0	33.0	Inbound SAR ping-pong
n	standard_sar_hi	-0:16:0.0	00:06:24.0	88.3	Inbound SAR imaging
o	standard_sar_hi	-0:09:36.0	00:01:15.0	3.8	SAR Turn transition to altimetry, beam 3 only
p	standard_altimeter_inbound	-0:08:21.0	00:00:55.2	11.0	Inbound altimetry
q	standard_altimeter_inbound	-0:07:25.8	00:01:39.0	22.8	Inbound altimetry
r	standard_altimeter_inbound	-0:05:46.8	00:04:46.8	57.4	Inbound altimetry
s	standard_sar_hi	-0:01:0.0	00:01:0.0	3.0	SAR Turn transition, beam 3 only
t	standard_sar_hi	00:00:0.0	00:08:30.0	117.3	Hi-SAR Main Swath
u	standard_sar_hi	00:08:30.0	00:00:27.0	1.4	SAR Turn transition, beam 3 only
v	standard_scatterometer_outbound	00:08:57.0	00:00:4.0	0.6	Atmospheric Probe with Tone
w	standard_scatterometer_outbound	00:09:1.0	00:00:2.0	0.3	Atmospheric Probe with Chirp
x	standard_altimeter_outbound	00:09:3.0	00:10:57.0	41.4	Outbound altimetry
y	standard_altimeter_outbound	00:20:0.0	00:09:30.0	18.2	Outbound altimetry
z	scatterometer_imaging	00:29:30.0	00:20:30.0	98.4	Outbound scatterometer imaging
lbrace	scatterometer_imaging	00:50:0.0	00:20:0.0	96.0	Outbound scatterometer imaging
vbar	standard_scatterometer_outbound	01:10:0.0	01:10:0.0	126.0	Outbound scatterometry raster
rbrace	standard_radiometer_outbound	02:20:0.0	03:40:0.0	13.1	Outbound radiometry
Total				1125.3	

Table 2: Division summary. Data volumes (Mbits) are estimated from maximum data rate and division duration.

Div	Alt (km)	Slant range (km)	B3 Size (target dia)	B3 Dop. Spread (Hz)
a	180802	off target	0.23	off target
b	110898	off target	0.14	off target
c	109268	off target	0.14	off target
d	43930	off target	0.06	off target
e	23325	24014	0.03	349
f	18758	20098	0.03	423
g	18400	19687	0.03	430
h	7969	8706	0.01	854
i	7562	7562	0.01	888
j	5055	5055	0.01	1180
k	5035	5035	0.01	1183
l	5025	5025	0.01	1184
m	4613	4767	0.01	1252
n	3896	4008	0.01	1391
o	2239	2329	0.01	1870
p	1964	1964	0.01	1983
q	1776	1776	0.01	2069
r	1477	1477	0.01	2221
s	986	986	0.00	2528
t	970	1005	0.00	2539
u	1995	2007	0.01	1969
v	2093	2093	0.01	1928
w	2108	2108	0.01	1922
x	2115	2115	0.01	1919
y	5055	5055	0.01	1180
z	7970	7970	0.01	854
lbrace	14535	14710	0.02	527
vbar	21041	21268	0.03	382
rbrace	43931	off target	0.06	off target

Table 3: Division geometry summary. Values are computed at the start of each division. B3 Doppler spread is for two-way 3-dB pattern. B3 size is the one-way 3-dB beamwidth

Each RADAR observation is represented to the project by a set of requests in the Cassini Information Management System (CIMS). The CIMS database contains requests for pointing control, time, and data volume. The CIMS requests show a high-level view of the sequence design. Table 1 shows the CIMS request summary for this observation. Although the CIMS requests show Low-SAR intervals, in reality the radar will be operated in Hi-SAR mode through most of this flyby.

The CIMS requests form the basis of a pointing design built using the project pointing design tool (PDT). The details of the pointing design are shown by the PDT plots on the corresponding tour sequence web page. (See https://cassini.jpl.nasa.gov/radar.) The RADAR pointing sequence is ultimately combined with pointing sequences from other instruments to make a large merged c-kernel. C-kernels are files containing spacecraft attitude data.

A RADAR tool called RADAR Mapping and Sequencing Software (RMSS) reads the merged c-kernel along with other navigation data files, and uses these data to produce a set of instructions for the RADAR observation. The RADAR instructions are called an Instrument Execution Block (IEB). The IEB is produced by running RMSS with a radar config file that controls the process of generating IEB instructions for different segments of time. These segments of time are called divisions with a particular behavior defined by a set of division keywords in the config file. Table 2 shows a summary of the divisions used in this observation. Table 3 shows a summary of some key geometry values for each division.

3 Overview

T91 is a full pass. The observation starts with two radiometer scans followed by a scatterometer scan in the northern hemisphere. Following this is a high altitude imaging segment with 8 scan lines providing beam 3 only SAR imaging of the northern polar seas. This is followed by regular altimetry and an atmospheric probe measurement. Then the radar collects standard SAR imaging data followed by altimetry and near nadir scatterometry collected over the methane seas. Then we have regular SAR imaging, another atmospheric probe measurement, low altitude and standard outbound altimetry, and high altitude imaging with 6 scan lines covering an area just south of the equator and adjacent to the T8 swath. The radar collection then ends with normal outbound scaterrometry and radiometry scans.

4 Mode Specific Operation and Performance

Many details of standard radar sequencing during the 4 main modes (Radiometry, Scatterometry, Altimetry, and SAR) have been discussed in previous sequence memos for prior observations. Refer to these for details. Some selected performance highlights are illustrated in figures and explained in the following subsections.

4.1 Coverage Layout

Figure 1 shows the layout of the different T91 data collections on a map of Titan. The close approach altimetry and near nadir scatterometry passes over one of the methane seas. Near nadir scatterometry is obtained by cycling through all 5 beams while nadir pointed. This special mode of operation is carried out in division Q from 7.4 to 5.8 minutes before closest approach. Only beam 3 covers the nadir point and collects standard altimetry data. The other beams are canted slightly away from nadir and provide low incidence backscatter measurements. Altimeter bandwidth mode is used on all 5 beams, so range slicing can be performed on the outer beams for improved range and incidence resolution. For the rest of the close approach altimetry which lasts from 8.3 to 1 minute before closest approach, regular altimetry is performed with a high data rate of 200 Kbps to collect the largest number of looks.

4.2 SAR Resolution Performance

For all of the SAR divisions the effective resolution can be calculated from the same equations used in the high-altitude imaging discussion. Figure 2 shows the results from these equations using the parameters from the IEB as generated by RMSS. The calculations are performed for the boresight of beam 3 which is the center of the swath.

Projected range increases with decreasing incidence angle, so the range resolution varies across the swath with better resolution at the outer edge. The SAR pointing profile decreases the incidence angle as time progresses and altitude increases, so there is progressive deterioration of range resolution away from closest approach. The projected

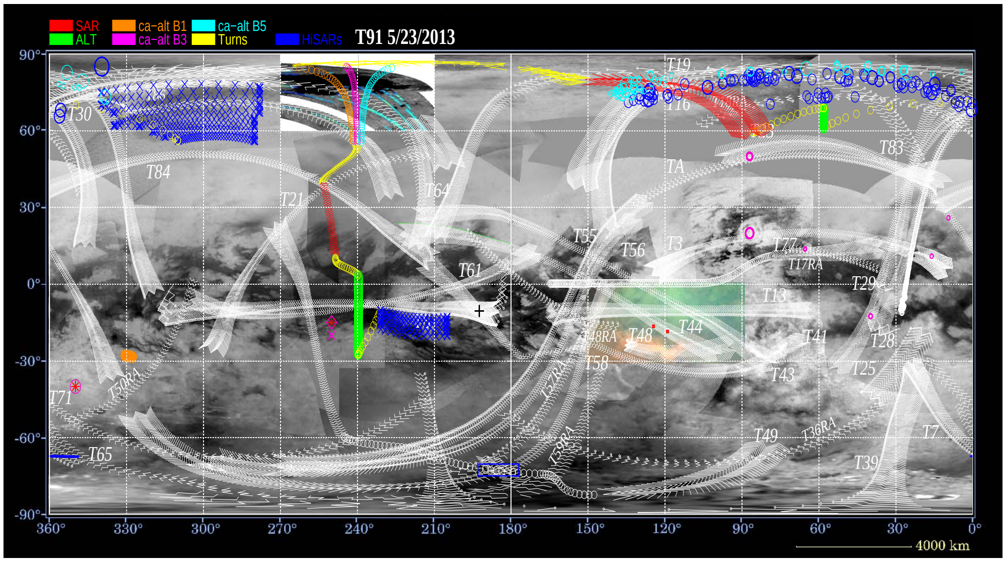

Figure 1: Coverage areas overlaid on Titan map showing prior optical and radar imaging.

range resolution rapidly deteriorates as the incidence angle decreases toward zero at the very beginning and end of the swath and during the close approach altimetry segment.

Azimuth resolution is a function of the synthetic aperture size which is determined by the length of the receive window in each burst (assuming the receive window is always filled with echos). Azimuth resolution deteriorates less quickly because the number of pulses and the length of the receive window are increased as altitude increases which mitigates the increasing doppler bandwidth of the beam patterns. The receive window length increases to fill the round trip time until the science data buffer is filled. At this point it is no longer possible to extend the receive window, and azimuth resolution starts to deteriorate more rapidly.

5 Revision History

1. March 13, 2014: Final release

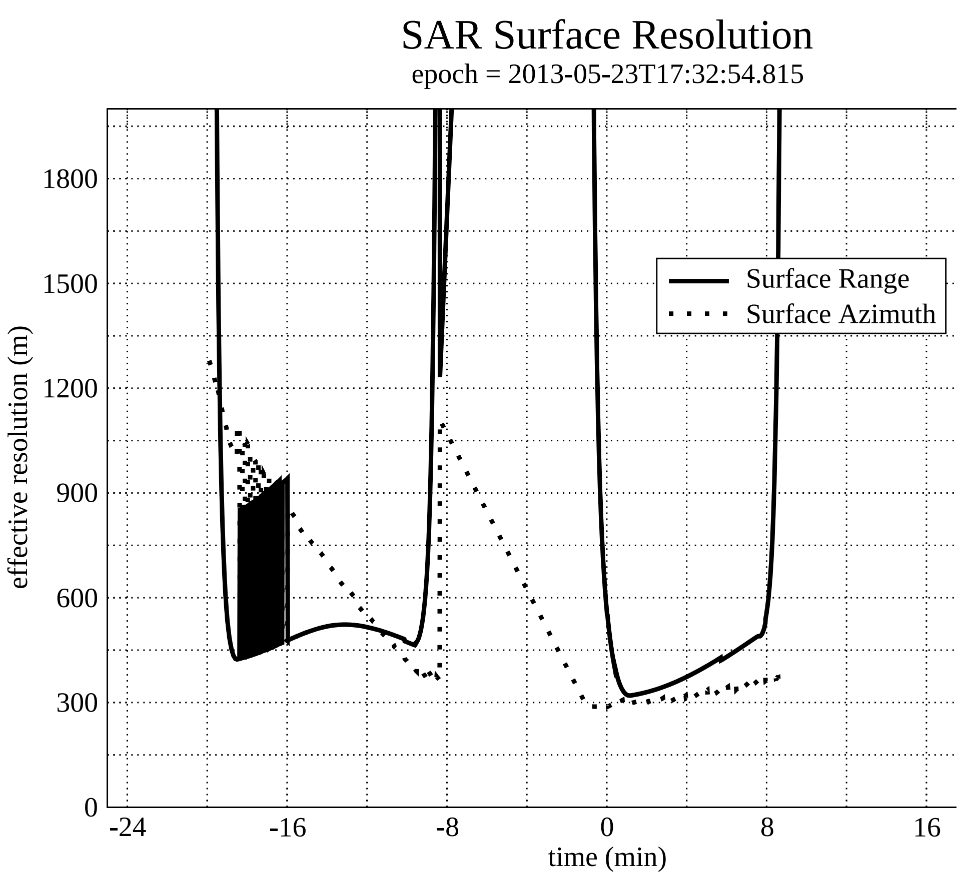

Figure 2: SAR projected range and azimuth resolution. These values are computed from the IEB parameters and are not related to the pixel size in the BIDR file. The pixel size was selected to be always smaller than the real resolution.

6 Acronym List

ALT	Altimeter - one of the radar operating modes
BAQ	Block Adaptive Quantizer
CIMS	Cassini Information Management System - a database of observations
Ckernel	NAIF kernel file containing attitude data
DLAP	Desired Look Angle Profile - spacecraft pointing profile designed for optimal SAR performance
ESS	Energy Storage System - capacitor bank used by RADAR to store transmit energy
IEB	Instrument Execution Block - instructions for the instrument
ISS	Imaging Science Subsystem
IVD	Inertial Vector Description - attitude vector data
IVP	Inertial Vector Propagator - spacecraft software, part of attitude control system
INMS	Inertial Neutral Mass Spectrometer - one of the instruments
NAIF	Navigation and Ancillary Information Facility
ORS	Optical Remote Sensing instruments
PDT	Pointing Design Tool
PRI	Pulse Repetition Interval
PRF	Pulse Repetition Frequency
RMSS	Radar Mapping Sequencing Software - produces radar IEB's
SAR	Synthetic Aperture Radar - radar imaging mode
SNR	Signal to Noise Ratio
SOP	Science Operations Plan - detailed sequence design
SOPUD	Science Operations Plan Update - phase of sequencing when SOP is updated prior to actual sequencing
SSG	SubSequence Generation - spacecraft/instrument commands are produced
SPICE	Spacecraft, Instrument, C-kernel handling software - supplied by NAIF to use NAIF kernel files.
TRO	Transmit Receive Offset - round trip delay time in units of PRI